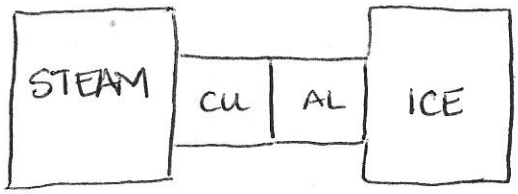
4C Problem set 2: Temperature, Heat and Thermal Properties of Matter

1. A piece of ice of mass m_i at 0°C is placed in mass m_w of water at 20°C. The system is in a container of negligible heat capacity and insulated from its surroundings. (a) What is the ratio of the mass of the ice to the mass of water required for all the ice to melt? (b) What is the equilibrium temperature of the system? (c) If the ratio of the mass is ½ ($m_w = 2m_i$), what fraction of the ice melts?

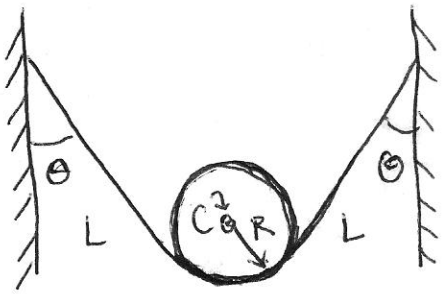
2. Two metal cubes, one copper (Cu) and one aluminum (Al), with sides of length a are arranged as shown. Find (a) the thermal resistance of each cube, (b) the thermal resistance of the two-cube system, (c) the thermal current H, and (d) the temperature at the interface of the two cubes.



3. A uniform thin rod of length L, mass M and linear thermal expansion coefficient α is pivoted at one end about a horizontal axis. Its temperature increases by Δt. What is the change, relative to the pivot, in the rod's (a) center of mass, (b) moment of inertia? (c) Suppose that the rod swings with small amplitude as a physical pendulum. Is the period increased or decreased? (d) by what amount?

4. A liquid with volume coefficient of thermal expansion β and bulk modulus B fills completely a sealed container with volume thermal expansion coefficient β', where $\beta' < \beta$. By how much is the pressure of the liquid increased when its temperature increases by ΔT?

5. A solid aluminum cylinder is suspended by a flexible steel belt attached to opposite walls at the same level, as shown. It is required that the axis C of the cylinder not be moved by thermal expansions and contractions of the cylinder and belt. The angle θ remains practically unaffected by temperature changes. Neglecting the weight of the belt, find the radius of the cylinder at temperature T if the length of each belt is L.



6. A blackened, solid copper sphere of radius $R = 4.0$cm hangs in a vacuum in an enclosure whose walls have a temperature of 20°C. If the sphere is initially at 0°C, find the rate at which its temperature changes, assuming that heat is transferred by radiation only.

7. A massless cylinder of length L rests on a horizontal frictionless table. The cylinder is divided into two equal sections by a membrane. One section contains nitrogen and the other contains oxygen. The pressure of the nitrogen is twice that of the oxygen. How far will the cylinder move if the membrane is removed?

8. Three insulated vessels of equal volume V are connected by thin tubes that can transfer gas but do not transfer heat. Initially, all vessels are filled with the same type of gas at a temperature T_o and pressure P_o. Then the temperature in the first vessel is doubled and the temperature in the second vessel is tripled. The temperature in the third remains unchanged. Find the final pressure P' of the system in terms of the initially pressure P_o.